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Weebit Nano Ltd

Clear line of sight to revenues

Share Price: A$0.395

ASX: WBT

Sector: Technology Hardware & Equipment

4 November 2019

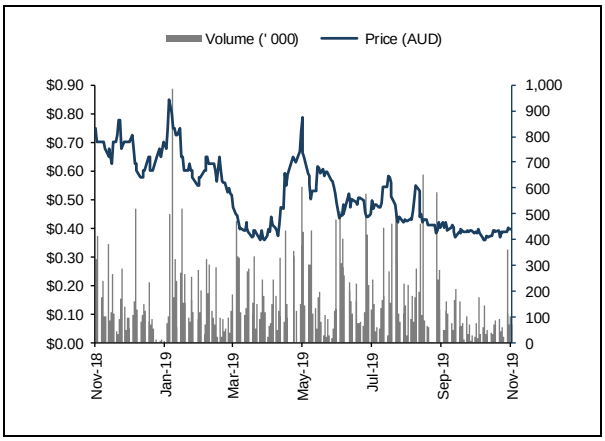
Weebit Nano Ltd. (ASX:WBT) is developing an emerging computer memory technology that combines the best of today's mainstream memory technologies, such as DRAM and Flash memory. WBT's SiOx ReRAM is non-volatile like Flash memory and is nearly as fast as DRAM. Due to its superior properties, including speed, data retention, power consumption and endurance, ReRAM is expected to complement and, most likely, partially replace some of these dominant memory and storage technologies.

Flash, DRAM, SRAM etc. are used in a wide range of products, such as micro controllers and sensors, which are found in most electronics used in consumer, industrial, automotive, medical and military applications. In other words, WBT's addressable end-markets are large and very diverse.

Market Cap. (A$ m)	28.4
# shares outstanding (m)	71.9
# share fully diluted (m)	84.2
Market Cap Ful. Dil. (A$ m)	33.2
Free Float	100%
12 months high/low	1.00 / 0.35
Average daily volume (x1,000)	165.3
Website	www.weebit-nano.com

Source: Company, Pitt Street Research

Share price (A$) and avg. daily volume (k, r.h.s.)



Source: Thomson Reuters, Pitt Street Research

Collaborations are the key to commercialisation

To date, the company has demonstrated working megabit arrays at 40nm resolutions and is currently targeting 28nm, which would be more than sufficient for most memory applications. The company has recently announced several collaborations in two key target markets, i.e. with China-based XTX and Kitec Design in Korea. We believe such partners, with their elaborate local networks, will prove to be the key to successful commercialisation. The work with Kitec has already resulted in a first potential customer in Korea.

Investment case: From lab to fab

WBT is currently entering the monetisation phase for its technology and is moving away from being a pure development company, i.e. the lab. We expect embedded ReRAM applications will present the first commercialisation opportunities in the near term. The market for embedded ReRAM, is expected to show very strong, long-term growth as it starts to complement some of today's mainstream memory technologies, such as NOR Flash and SRAM. There is even potential to replace NOR Flash in certain applications.

On the back of some of the aforementioned industry collaborations announced in 2019, we expect the company to be able to start landing commercial licensing deals in 2020, paving the way for SiOx ReRAM to eventually move into production fabs. Please refer to the SWOT analysis for an overview of investment risks associated with WBT.

Valuation of A$1.65 per share

If WBT can secure multiple customers, in the embedded memory space initially, we believe the shares can rerate towards valuation levels seen in recent M&A transactions in the semiconductor IP (Intellectual Property) and memory industry, i.e. towards A$1.65 per fully diluted WBT share.

Valuation metrics	
Fair valuation range (A$m)	135
Valuation per share (A$)	1.65

Source: Pitt Street Research

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Please note Pitt Street Research and/or its directors hold stock in Weebit Nano per the date of this report.

Analyst: Marc Kennis

Tel: +61 (0)4 3483 8134

marc.kennis@pittstreetresearch.com

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ReRAM in a nutshell

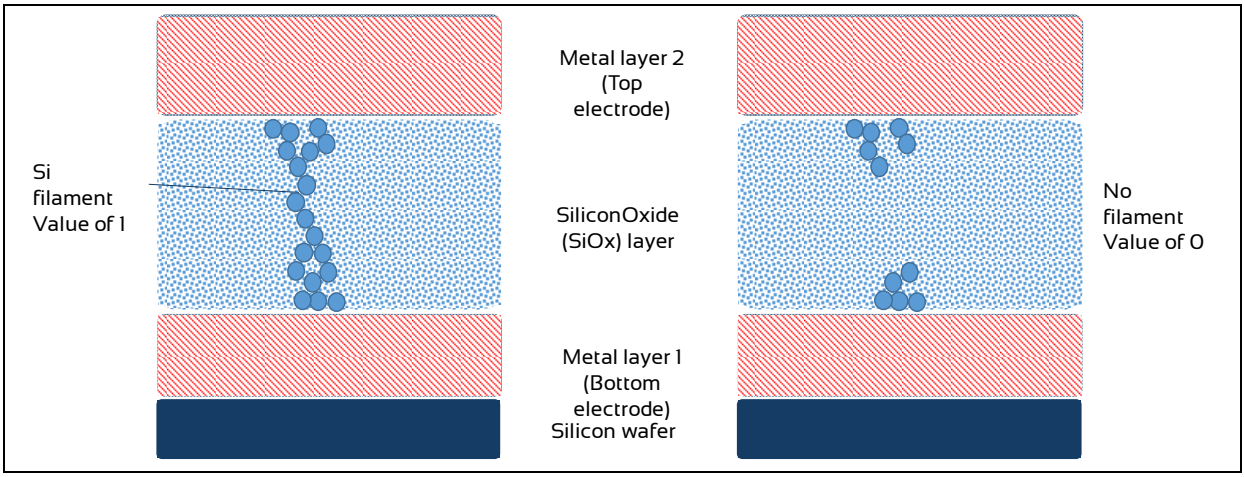
Weebit Nano (ASX:WBT) is developing a newly emerging type of computer memory technology, called Resistive RAM or ReRAM, that can potentially complement or substitute existing memory and storage technologies in computer chips used today.

As opposed to charged-based memory technologies, like DRAM, Flash, SRAM etc., that require an electric charge to represent a value, ReRAM cells work by changing the resistivity level of the memory cell.

Silicon Oxide ReRAM

The specific ReRAM technology that WBT has developed is called Silicon Oxide ReRAM, or SiOx ReRAM. The technology is based on the forming of a conductive channel between the two metal electrodes of a ReRAM cell. These electrodes are typically made out of metals, such as titanium, tungsten, aluminum or copper. The conductive channel is formed inside a non-conductive Silicon Oxide (SiOx) layer.

Figure 1: Cell switching by forming and breaking a silicon filament in a SiOx switching layer



Source: Pitt Street Research

SiOx has typically been used as an insulating component in semiconductor manufacturing. However, by applying a certain voltage to one of the electrodes, a switchable conductive pathway of silicon nanowires (filament) can be formed within the SiOx layer (see Figure 1). In this high conductivity, low resistance state, the cell value is 1. By subsequently applying a reverse voltage to the electrode, the filament can be broken down again, effectively switching the memory cell back to the original state of 0.

Please refer to Appendix I for a full review of the technology.

SiOx can be processed using existing manufacturing processes

SiOx ReRAM is easily integrated into existing manufacturing processes

Because silicon has been the basic resource for manufacturing of semiconductors for decades, the properties of the material are very well understood by chip manufacturers. Furthermore, since deposition of SiOx insulating layers is a common processing step in semiconductor technology, the deposition of SiOx layers doesn't require the introduction of materials or tools that are new to the semiconductor production process. Consequently, SiOx ReRAM can be manufactured using existing manufacturing processes and

tools in any commercial fab, which we believe may expedite the integration of the technology into prospective customers' existing and future chip designs.

ReRAM has several key advantages over today's technologies

The reason ReRAM is potentially a very attractive alternative to existing memory and storage technologies is threefold:

- **Speed**; ReRAM can achieve access speeds close to those seen in DRAM (~50ns, nano seconds), which is substantially faster than NAND Flash (50,000ns).
- **Operating Voltage**; ReRAM can operate using lower voltages (2V) to switch the memory cells from one resistive state to the other, while charged-based memory technologies such as Flash require write voltages of 10-12V. This becomes very significant for embedded applications, since such high voltages need to be generated on chip, which is costly in terms of area and power.
- **Power consumption**; Switching the resistive state of a ReRAM memory cell require low power of less than 10pJ, which is about 3 orders of magnitude lower as compared to Flash technologies. Because Flash memory state switching is based on injecting charges over an insulator barrier, the typical power consumption for Flash write operation typically exceeds 10nJ. When aggregated, these differences lead to a ~1,000x lower power consumption for ReRAM compared to Flash memory.
- **Endurance**; ReRAM cells can be switched more than 1m times, compared to 1,000-100,000 for different forms of Flash Memory. Higher endurance means slower degradation of the memory cells compared to many of today's technologies.

The many application areas of ReRAM

Embedded Memory

Complementing existing memory technologies in the embedded market

Because of its superior properties compared to a number of existing technologies, WBT's ReRAM technology can potentially replace and/or complement embedded Flash, used in densities up to 2Gb in devices such as mobile phones, medical equipment, autonomous vehicles, IoT devices and scientific instruments.

Embedded ReRAM could be used to store:

- Security keys that preferably shouldn't be read from outside memory given the vulnerabilities involved;
- Core parts of firmware for fast boot and security;
- Lookup tables and coefficients for Artificial Intelligence, and
- Coefficients for analogue devices, i.e. sensors which are used for fine tuning.

Discrete memory devices

Stand-alone memory devices

ReRAM can also be used in so-called discrete memory devices, i.e. devices which are 100% memory. For instance, discrete devices such as DRAM (Dynamic Random-Access Memory) can be used to support graphics cards in computers (Graphic Processing Unit, or GPU) and Central Processing units (CPU).

Another discrete memory application is Storage Class Memory (SCM), which refers to the use of newly emerging memory technologies for use as large scale

storage capacity, e.g. on mobile phones, laptops and in data centers. WBT's current focus is on embedded memory where it believes it can generate revenues faster, and it plans to expand to discrete memory applications as its next step.

Neuromorphic Computing

Application in neuromorphic computing

Neuromorphic computing (NC) is another fast-growing area of interest for WBT given that the structure and properties of ReRAM cells make the technology very well suited for NC. As we will explain below, ReRAM cells function in a way which is very similar to a synapse in our brain, so a ReRAM memory can learn like our brain does and then infer a result based on the input it gets. NC will allow emulating the structure and functioning of the biological brain, enabling substantially faster and more efficient Artificial Intelligence (AI) applications.

Weebit Nano's addressable market is very large

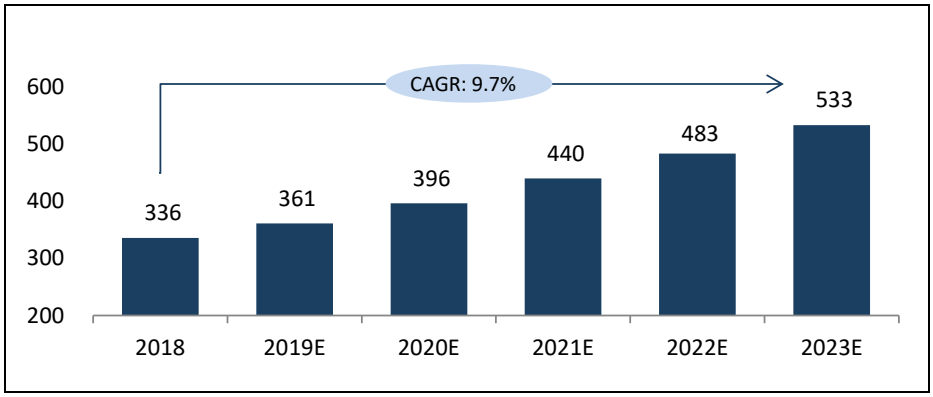
The two identified potential near and mid-term application areas for WBT's technology are the embedded non-volatile memory (NVM) market and the discrete memory market. NC is a long-term application area which we expect to be a very large one in due time, but the size of which is currently very hard to estimate. WBT is initially targeting the embedded NVM market, but the discrete memory market may be a close option if sufficient traction can be garnered from potential licensees.

1. Embedded NVM is WBT's most direct path to market

WBT is initially targeting the embedded NVM market, with the delivery of the first module by June 2020

WBT has prioritised the delivery of the first memory module to potential customers, and inroads may be made in the growing embedded NVM IP market by mid-2020. According to Semico Research, an independent market research company, the embedded NVM IP market is expected to post a CAGR of 9.7% over 2018–2023 to reach US$533m (Figure 2). Market growth is attributable to the increasing penetration of IoT-based devices and ever-growing data requirements of mobile phones, Artificial Intelligence (AI) and virtual reality (VR).

Figure 2: Global embedded NVM IP market (US$m)



Source: Semico Research Corp.

ReRAM's superior properties make it one of the largest growth contributors

The existing NVM solution for embedded memory (Flash memory) has many drawbacks. While discrete NVM Flash products continue to scale down using complex processes such as 3D NAND, there is currently no Flash-based option for scaling down embedded NVM solutions below 28nm.

Furthermore, it doesn't scale beyond 28nm in 3D Flash and Flash is a Front End Of Line (FEOL) technology, which means that it is embedded in the transistor level as a part of it sits next to the core chip design and is therefore manufactured in the early stage of the entire chip manufacturing process. Flash memory therefore also impacts the design of the entire chip, which poses big challenges in certain applications, mostly in the case of Analog chips.

SiOx ReRAM is a BEOL process, which means there is no effect on the core design of the chip

In contrast, ReRAM is a Back End Of Line (BEOL) process, meaning it is manufactured at the end of the entire manufacturing process on top of the core design with no effect on this core design of the chip. This also implies that ReRAM modules can be simply integrated on every given core process, which simplifies the design process substantially and provides the opportunity to integrate ReRAM all the way down to 7nm and below.

In part because of these differences, SiOx ReRAM technology only requires 1 or 2 additional masks (blueprints of the chip design used in the manufacturing process) versus 5 to 10 extra masks for embedded Flash. A mask set typically costs up to several million dollars and needs to be replaced after a given number of production cycles. So apart from the simpler design process, the cost benefit of ReRAM is also very substantial for chip manufacturers.

SiOx ReRAM is 1,000x more energy efficient than Flash

Furthermore, compared to Flash memory (such as NAND/NOR), ReRAM has demonstrated higher speeds (1,000x faster) and lower energy consumption (1,000x more energy efficient).

Lastly, compared to other emerging memory technologies, WBT's SiOx ReRAM is much cheaper, easier to manufacture and more energy efficient than other emerging technologies, such as Magnetic RAM (MRAM).

As a result, WBT's SiOx ReRAM technology is expected to be one of the largest contributors to the expected growth.

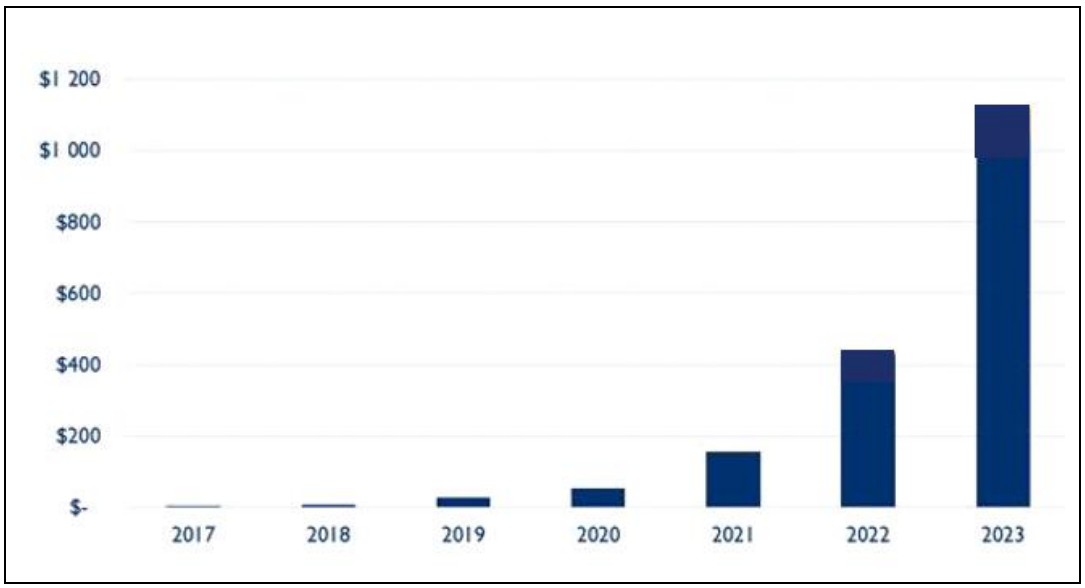
Exceptionally strong growth expected for embedded ReRAM

While the absolute levels of projected revenues differ from one market forecaster to another, they all see exceptionally strong growth for embedded ReRAM in the next 4-6 years.

Yole Développement expects the market for emerging NVM technologies to grow from several tens of millions of dollars in 2019 to nearly US$1.2bn in 2023 (Figure 3).

Mordor Intelligence estimates the memristor[1] market, which is broader than just emerging NVM, will grow from USD278m in 2018 to approximately USD8.9bn in 2024, or a CAGR of 52.7% during the period 2019 through 2024.

Figure 3: Embedded emerging NVM market (US$m)

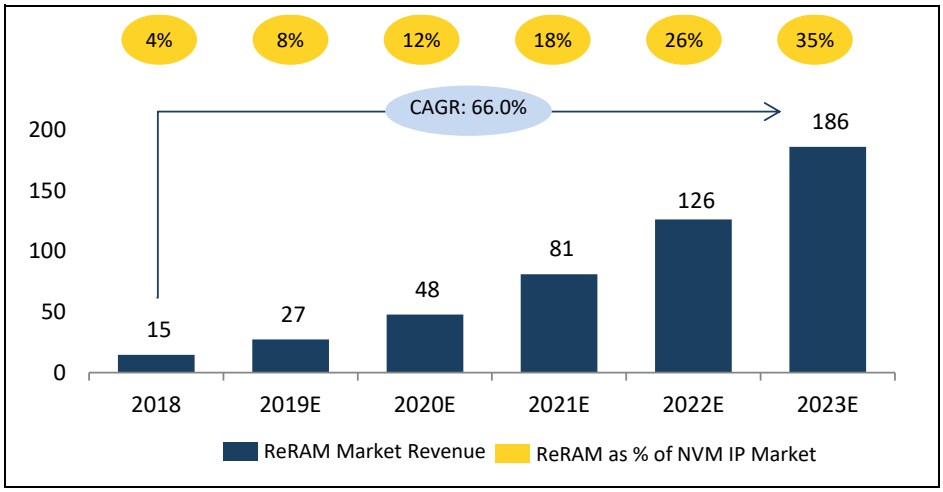


Source: Yole Développement

[1] 2-terminal non-volatile memory devices based on resistance switching.

Semico Research is more conservative, estimating the ReRAM market to grow at rate of 66.0% to reach US$186m in 2023 (Figure 4). Most of this is expected to be generated by royalties that licensees pay to IP owners, such as WBT and doesn't include manufacturing revenues for IDM's.

Figure 4: ReRAM market revenue (US$m)



Source: Semico Research Corp.

SiOx ReRAM can be easily integrated into existing CMOS processes

ReRAM technology is easy to integrate with standard CMOS devices, which should lead to a short time-to-market

ReRAM technology is versatile and apt for use in embedded memory, such as in IoT devices and Systems on a Chip (SoC). The potential to embed ReRAM technology into logic chips and entire systems (SoC) can present substantial commercial opportunities. As SiOx ReRAM is CMOS compatible, it should have a relatively short time-to-market once licenced to a semiconductor manufacturer.

WBT's technology is based on standard materials and can be manufactured using existing semiconductor manufacturing tools working in fabs today, which gives it a competitive advantage over other ReRAM technologies that require new tools and/or processes in order to be adopted in a fab. This should enable WBT to potentially capture a significant market share in the market for emerging embedded NVM.

2. Discrete memory is another potential market for WBT

NVM is generally used for secondary storage applications as the main forms of NVM, like NAND Flash memory, have limitations that make them unsuitable for use as primary storage, i.e. working memory. However, next-generation memories, such as ReRAM, provide the benefits of non-volatile Flash memory and the speed of volatile RAM.

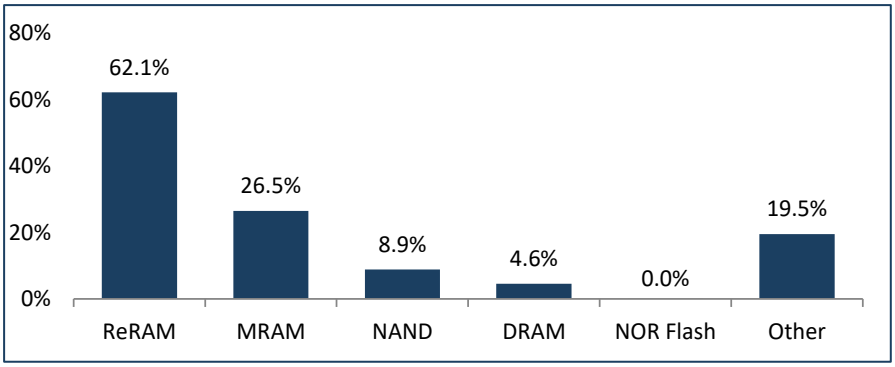
ReRAM being targeted for SCM market would open up additional growth opportunities for WBT

Simply put, ReRAM and other emerging technologies are expected to fit between main memory (DRAM) and storage (NAND Flash) in systems, where there is a growing latency gap. Hence, they are being targeted for the storage-class memory (SCM) market. This opens up additional end-market applications for ReRAM, and WBT could benefit if it can generate sufficient traction from potential licensees.

Currently, the usage of ReRAM in the SCM market is miniscule, but Semico Research etimates its usage to grow sevenfold between 2019 and 2023,

posting a CAGR of 62.1% (Figure 5). We do not expect ReRAM to replace DRAM or NAND any time soon, but rather we believe that ReRAM will complement them. In the long term, we believe there is scope for ReRAM to replace NAND Flash, but that will likely be a very gradual process.

Figure 5: 2019–2023 CAGR of Discrete Memory market – by product



Note: CAGR based on number of units sold
Source: Semico Research, Pitt Street Research

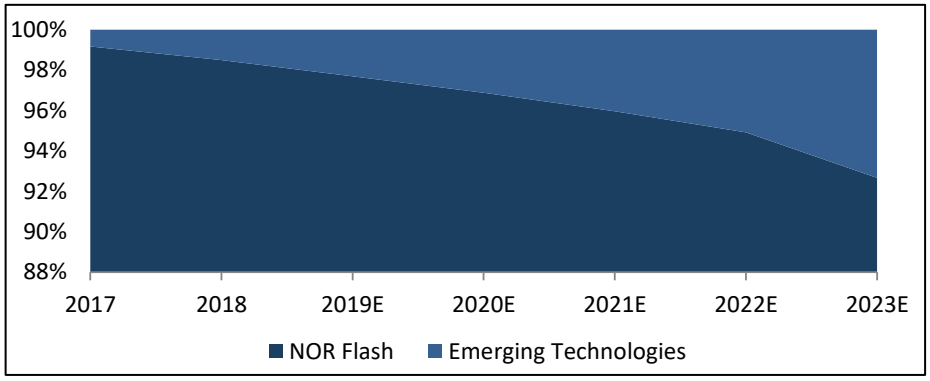
Emerging technologies will eventually replace NOR Flash

Emerging NVM to increase its market share almost fivefold

Most NOR Flash vendors have signalled end-of-life of small-density NOR Flash parts. Hence, it is anticipated that emerging technologies, such as ReRAM, MRAM, FeRAM, STT-RAM, CBRAM and NRAM, will displace incumbents' technologies such as NOR Flash.

Semico Research estimates that the share of NOR Flash may dip from 98.5% to 92.7% between 2018–2023, while that of emerging technologies may rise from a mere 1.5% to 7.3% (Figure 6).

Figure 6: Share of NOR Flash compared with emerging technologies



Source: Semico Research Corp., Pitt Street Research

ReRAM well placed to compete with NOR Flash

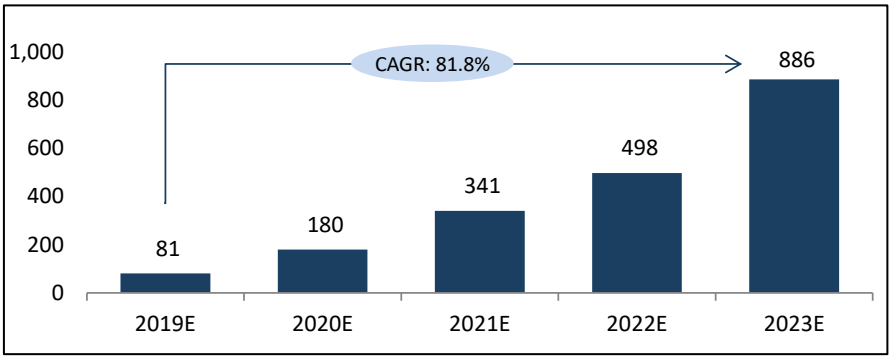
Immediate applicability of ReRAM in small densities for legacy products

The majority (about 73%) of NOR Flash units are at the 32Mb density or below, which this represents a good potential for ReRAM. We believe that ReRAM could compete very well in this space with older NOR Flash parts. Most smaller density NOR Flash parts are deployed in legacy applications where the designers cannot afford to redesign the solution to take advantage of newer technologies or cannot charge more for the solution if they redesign it. Thus, we believe a new technology like ReRAM, which is just starting its life cycle

and is targeted at these smaller densities, would have wide acceptance in the market. Favourably, ReRAM uses a two-terminal selector and can thus be packed very densely.

On the back of the potential to replace NOR Flash and increasing acceptance by industry players, Semico Research expects ReRAM to witness a very solid CAGR of 81.8% over 2019–2023 (Figure 7).

Figure 7: ReRAM discrete memory market size (US$m)



Source: Semico Research Corp., Pitt Street Research

XTX collaboration to replace NOR Flash

XTX deal specifically to replace NOR Flash with ReRAM

As we will elaborate on below, we believe WBT's recent collaboration with XTX in China is aimed at just this opportunity, i.e. replacing NOR Flash with ReRAM. XTX has a range of NOR Flash products and we believe the aim of their collaboration with WBT is to replace NOR Flash with ReRAM to take advantage of all the benefits ReRAM has to offer.

3. Neuromorphic computing is a future application for ReRAM

Neuromorphic computing performs computational functions similar to the biological brain to enable AI and machine learning. The suitability of ReRAM for neuromorphic computing is related to the memristor's ability to modify its state based on the history of voltages applied to it. In other words, it has the temporal and analogue qualities of biological neurons and synapses, i.e. a ReRAM cell not only has an aggregate memory of past inputs but can propagate an output in response to an input based on that aggregate memory, just like a biological brain.

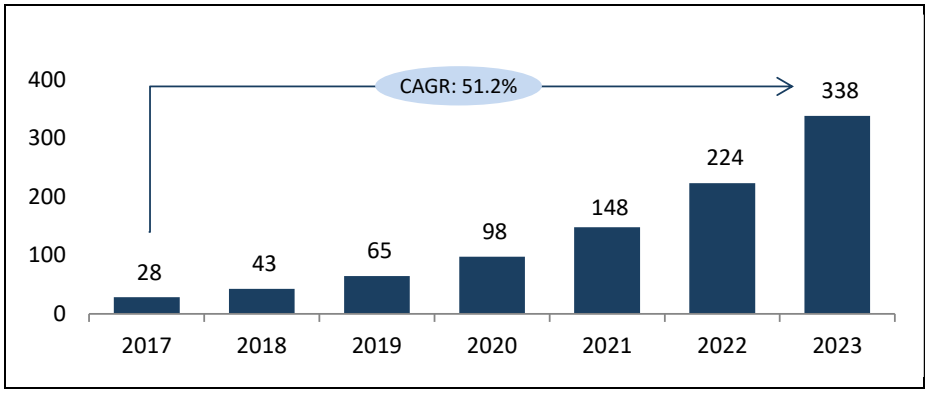
ReRAM cell structure resembles biological synapse

As the ReRAM cell structure resembles biological synapses, the technology can potentially be tweaked to serve AI applications in a way that will be much faster and cheaper (less energy consumption) than software-based neural networks. There is a broad future applicability of hardware-based neuromorphic chips in areas such as autonomous driving, advanced driver assistance (ADAS) and edge computing.

Growing fast from a small base

Although the neuromorphic computing market is still small, it is expected to take off in the near term. According to Knowledge Sourcing Intelligence, the neuromorphic computing market was valued at US$28.3m in 2017 and is expected to grow at a CAGR of 51.2% during 2017–2023 to reach US$338.1m (Figure 8).

Figure 8: Global neuromorphic computing market (US$m)



Source: Knowledge Sourcing Intelligence, Pitt Street Research

Major factors driving this growth include the increasing use of neuromorphic chips for developing cognitive robots, and growing demand for AI in applications, such as language and image processing, computer vision, non-linear controls & robotics and translation & chatbots. As far as end-use segments are concerned, consumer electronics accounted for 60% of the total market in 2016, followed by the automotive, healthcare and military & defense segments.

That said, WBT is just starting out on the path to neuromorphic chips through collaborations with research institutes like IIT Delhi and Politecnico di Milano. This development process is likely to take at least several more years.

Spiking Neural Networks already demonstrated on ReRAM

However, Weebit and development partner Leti already demonstrated the world's first Spiking Neural Network (SNN) running on ReRAM technology at the Flash Memory Summit in August 2019.

Gartner expects neuromorphic chips to be initially used in IoT edge devices due to their ability to execute certain levels of neuromorphic computing at the edge, reducing internet bandwidth and central processing requirements.

Revenue model focussed on technology licencing

Focusing on the embedded market first

Given the huge cost involved in developing and commercialising semiconductor IP, WBT is developing SiOx ReRAM technology with its French research collaboration partner, Leti. To leverage the substantial commercial potential of the technology, the company will licence it to other providers in the semiconductor industry. WBT is initially targeting the embedded memory market, but is expected to expand into other domains, such as neuromorphic computing and storage markets, later.

ReRAM to generate three separate revenue streams

WBT is expecting to generate revenues from three separate, but related streams, which are paid per customer project/product (Figure 9):

1) non-recurring engineering (NRE) work related to specific integration needs,

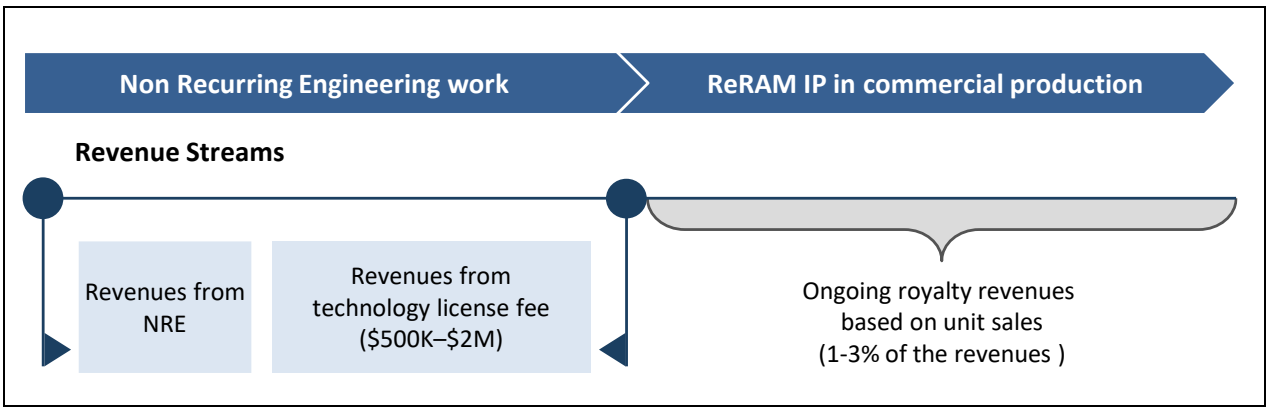
2) one-off licencing payments, and

3) royalties from customers' sales of semiconductors that use WBT's ReRAM technology.

Potentially multiple revenue streams per customer

Importantly, the license fees apply to each customer project/product individually. Customers may have multiple projects/products that incorporate WBT's SiOx ReRAM technology and hence WBT will be able to derive multiple revenue streams from a single customer.

Figure 9: Predicted revenue streams for WBT's SiOx ReRAM technology



Source: Pitt Street Research

NRE fees: WBT is targeting the embedded memory market, where ReRAM will be combined with other modules into an SoC. While prospective customers, such as integrated device manufacturers (both logic and memory), foundries and design houses, have their own specific requirements for the integration of ReRAM into their design (how the module fits into their system, including size, shape and the number of read/write ports), customisation requires intensive design work that can take 6–9 months. The one-off NRE fees cover WBT's costs to adapt the technology to customer-specific needs. NRE fees vary widely across the industry, from several hundreds of thousands of dollars to millions of dollars. In WBT's case we expect NRE costs per customer to be less than US$500k.

IP licencing fees: Customers typically pay a one-off licence fee for the use of the technology. IP licencing fees, paid upon engagement, typically range from

~US$100k to >US$1m per licence. Non-exclusive licencing will enable WBT to sign multiple licensees to expand its revenue generating potential.

Royalties: We believe the most lucrative future revenue stream for WBT will be royalties paid by customers for each chip they sell that includes WBT's SiOx ReRAM IP. These royalties are usually a percentage of the customer's revenue from sales and range from 1% to 3% (typically ~1.5%).

Example: Assume WBT entered into a licencing agreement with a semiconductor company to licence its technology with specific integration requirements. Terms could include US$500k of NRE fees, US$500k in one-time licencing fee and 1.5% royalty on sales from each of its chips that incorporates SiOx ReRAM (the licensing fees and royalty percentages are usually linked, i.e. a higher license fee is typically combined with a somewhat lower royalty percentage and vice versa).

Further assume that this customer will sell 1m, 5m, 10m and 15m of these chips in years 1 through 4, respectively, at US$5 each.

In this example WBT will recognise the following three revenue streams from this customer:

1) NRE fees of US$0.5m.
2) One-time licencing fees of US$0.5m before the start of production.
3) Royalties of US$75k (1m x US$5 x 1.5%), US$375k, US$750k and US$1.3m, respectively, in the first 4 years of production.

Current collaborations provide line-of-sight to revenues

WBT commenced detailed work for a first potential customer in Korea

In May 2019, WBT announced that its SiOx ReRAM technology had achieved technical parameters that are in line with today's market requirements, i.e. endurance and retention levels equivalent to or better than in today's commercially sold NVM products. This has enabled the company to start engaging with an initial potential customer, i.e. WBT is currently focussed on developing its memory module to meet the unique specifications of this first potential customer in Korea. It is expected to deliver this memory module by mid-2020.

Korea is the world's largest memory chip manufacturer, accounting for ~57% of the global supply, and is a key target region for WBT's SiOx ReRAM technology. WBT appointed a leading semiconductor distributor, Kitec Design Co Ltd (Kitec), as its Korean market representative to assist in discussions with strategic customers and partners. Kitec has been an established representative in semiconductor industry for about 20 years. More importantly, it specialises in promoting electronic design automation (EDA) and IP companies in the South Korean market. As WBT moves closer to productisation, we believe Kitec's strong connections with the major firms in the South Korean market will be instrumental in inking multiple licencing deals in the region.

Developing a memory module and working towards technology transfer

WBT has so far engaged with one tier-2 provider of SoC development and design services that operates its own fab. The collaboration is focused on developing a memory module based on this manufacturer's specifications and ultimately a transfer of the technology to this manufacturer's production facilities.

Inroads into vast Chinese market

Chinese semiconductor market is growing fast

The company is also exploring opportunities in China. The Chinese semiconductor industry is growing at a healthy pace and is expected to attain US$129bn revenues by 2020 – nearly a third of global revenues. Further, the Chinese government allocated a US$47.4bn fund for development of the industry in 2018, which has made China a lucrative destination for semiconductor firms.

XTX could be a major catalyst for uptake of SiOx ReRAM in China

Recently, XTX Technology (XTX), a leading provider of a variety of Flash-based NVM solutions, signed a letter of intent (LoI) with WBT to investigate ways to use SiOx ReRAM technology in its products. We believe XTX may be planning to enhance or replace some of its products that are based on outdated technology (NOR Flash) with WBT's SiOx ReRAM. XTX has about 2,000 customers, including some renowned global semiconductor companies, and any positive development between the companies is expected to accelerate the revenue generation process for WBT.

Additionally, XTX and WBT are exploring potential cooperation in sales and marketing activities in China, which would help WBT target more companies in one of its largest target markets.

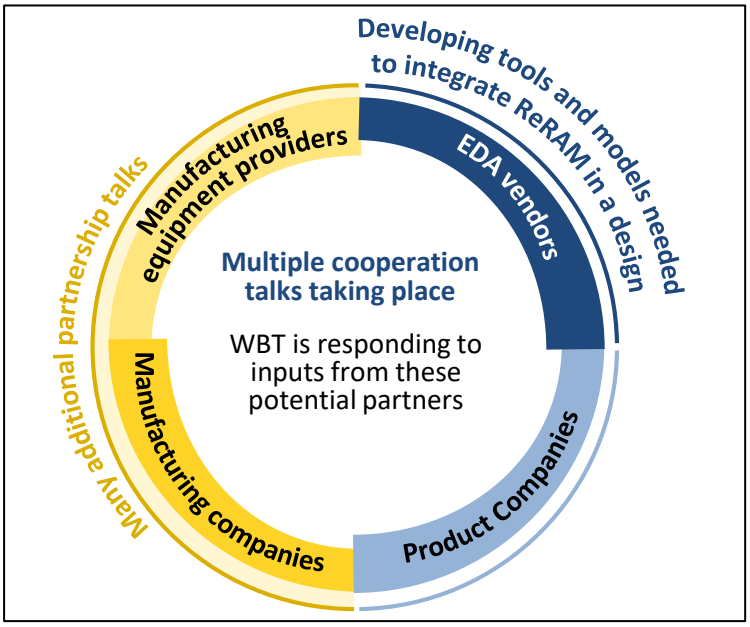
Dedicated VP for China to accelerate commercial roll out

To further drive the company's efforts in China, WBT appointed Jackson Lam as VP, Strategic Alliances, China, in December 2018. He is a semiconductor veteran and has almost 40 years of experience in the Chinese semiconductor industry. Mr. Lam is responsible for WBT's partnerships in China, including customers and potential industry partners. Over the past 12 years, he has aided numerous Israeli firms in setting up and expanding their businesses in China. We believe his understanding of the dynamics of the Chinese market bodes well for potential future deals in the region.

WBT is engaging with a broad spectrum of industry participants

WBT is engaging with a number of potential customers and partners (Figure 10) as part of its move from development to commercialisation and productisation.

Figure 10: Targeting various industry participants



Source: Company

Dedicated VP for China to accelerate commercial roll out

Upon successful completion of the transfer of ReRAM IP from lab to fab, expected by the end of 2020, we believe WBT should be in a position to secure a variety of customer types for ReRAM, including memory players, semiconductor foundries, third-party semiconductor IP providers and integrated device manufacturers (IDMs), for various end-market applications such as internet of things (IoT), analogue and artificial intelligence (AI).

A broad range of likely commercial partners

Collaboration partner Leti may provide further inroads into prospective customers

In our opinion, semiconductor foundries such as TSMC, UMC and GlobalFoundries will be interested in offering ReRAM solutions to customers, especially for embedded memory and SoC applications at high resolutions, i.e. small geometries with logic elements <16nm.

Considering its strong R&D engagement with Leti, which has strong inroads into global semiconductor companies – including key embedded memory and logic manufacturers, such as Intel and STMicroelectronics – we believe these semiconductor giants can be potential future licensees of WBT's technology.

We also believe that some of the major players in the embedded memory market, such as Microchip Technology, HHGrace, Synopsys, eMemory Technology and SST, will likely be interested in adopting WBT's next-generation embedded memory technology.

Analysing the different addressable markets for ReRAM, we believe SK Hynix, Western Digital, Samsung and Panasonic may potentially be interested in licencing WBT's technology for storage-class memory (SCM) applications.

Significant progress with partners to enable expansion of end markets

WBT continuing to progress with partners to help expand addressable target markets

WBT has also partnered with Silvaco, an Electronic Design Automation tool provider, to model the electrical behaviour of SiOx ReRAM devices. This partnership is expected to accelerate the incorporation of WBT's ReRAM modules into OEM customers' designs.

Additionally, its collaboration agreement with Technion, one of Israel's leading technology research institutes, will test WBT's ReRAM technology in real processing-in-memory (Real PIM) environments – which entails use of memory cells to perform logic functions, i.e., structure them such that they actually form logic gates. This work can potentially be very useful for future AI applications using ReRAM technology and should be seen in light of the opportunities in Neuromorphic Computing.

Similarly, WBT is collaborating with IIT Delhi, a leading engineering institute in India, and Politecnico di Milano, a leading technical university in Italy, to develop ReRAM's potential in the field of hardware-based AI. As the ReRAM cell structure resembles biological synapses, the technology can potentially be tweaked to serve AI applications in a way that will be much faster and cheaper (less energy consumption) than software-based neural networks. This will lead to a broad future applicability of hardware-based neuromorphic chips in areas such as autonomous driving, advanced driver assistance (ADAS) and edge computing in IoT devices.

WBT's research efforts with these partners should ensure that it leverages SiOx ReRAM's full capability across advanced applications.

A board made up of semiconductor rock stars

Former Intel and AMD heavy weights driving the business

WBT's board comprises seven members, a majority of whom have over 40 years of experience across domains, including the NVM space in the semiconductor industry. We believe the vast industry experience of these board members (Figure 11) may expedite WBT's upcoming commercialisation phase.

Figure 11: Board Members

Name and Position	Position (Director Since)	Years of Exp.	Affiliations (Current and Past)
David Perlmutter	Chairman (Aug-16)	40	Intel and Mellanox Technologies
Coby Hanoch	CEO (Oct-17)	40+	National Semiconductor, Verisity, PacketLight and Jasper
Yoav Nissan-Cohen	Executive Director (Feb-18)	40+	Tower Semiconductor, Amimon, Saifun Semiconductor, and Zullavision
Atiq Raza	Non-Executive Director (July-19)	40+	AMD, Calient Technologies, Magma Design, Matrix, Mellanox, NexGen, RMI Corporation and Solantro Semiconductor
Ashley Krongold	Non-Executive Director (Sep-16)	25	ANZ Private Bank, Dotz Nano, Investec Bank, Krongold Group, and William Buck Chartered Accountants
Fred Bart	Non-Executive Director (Mar-18)	40+	Audio Pixels Holdings, Bart Group, Electro Optics Systems, and Immunovative Therapies

Source: Company, Pitt Street Research

The Intel pedigree of WBT's chairman, **David Perlmutter**, will likely be instrumental in developing highly relevant relationships with respect to the licencing of WBT's technology. The company's CEO, **Coby Hanoch**, an industry veteran with a strong commercialisation background, has hands-on experience in leading companies from early-stage development to market, which is well suited to WBT's upcoming commercialisation phase. **Yoav Nissan-Cohen** (Executive Director) **did his PhD in NVM under Prof. Dov Frohman, who invented the first NVM.** He also founded Tower Semiconductor, one of the top fabs worldwide. His extensive experience in NVM technology and fab operation are extremely valuable to WBT.

Recently appointed non-Executive Director **Atiq Raza** is an industry veteran with deep technical understanding and substantial experience in defining market-winning strategies and running businesses. His extensive contacts with industry leaders and investors should be very beneficial for WBT. The company's other directors, **Ashley Krongold** (an Australian investment banker with an accounting background) and **Fred Bart** (who has extensive experience in developing collaborative partnerships and alliances) have strong track records with regards to running ASX-listed technology companies.

Board details

David Perlmutter (Chairman): David has almost 40 years' experience in the semiconductor industry and has held a number of senior global positions, including EVP and GM at the Intel Architecture Group (IAG) and Chief Product Officer of Intel Corporation. He was directly responsible for developing several of Intel's major products and had a huge impact on Intel's global business. David received an award for innovation in industrial development from the Israeli President in 1987 for the i387 math coprocessor, which he developed during his stint at Intel. Additionally, David is a member of the board of directors of Mellanox Technologies and chairs various non-profit organisations. He is also a member of the board of governors of the Technion Israel Institute of Technology and on the board of directors of several semiconductor start-ups.

Coby Hanoch (CEO): Coby has been active in the semiconductor industry for 40 years, including an 11-year stint at National Semiconductor. He was most recently CEO at EDAcon Partners, where he provided business development, sales and marketing support for small companies, helping start-ups define their corporate and sales strategy, and raise capital. Mr. Hanoch also served as the VP Worldwide Sales at Verisity, an electronics design verification software company, where he was part of the founding team and grew the company to over US$100m in annual sales, facilitating its acquisition by Cadence Design Systems for US$315m. Additionally, he was VP Worldwide Sales at Jasper, the sales of which he doubled in three years before it was acquired by Cadence for US$170m. Additionally, as CEO of PacketLight, Mr. Hanoch helped steer the company away from bankruptcy.

Dr. Yoav Nissan-Cohen (Executive Director): Yoav brings nearly 40 years of scientific research, technology development and executive management experience in the hi-tech industry. He received his PhD for researching non-volatile memories, under the supervision of Prof Dov Frohman, the inventor of the first non-volatile memory technology. Mr. **Nissan-Cohen** played a key role in the formation of Tower Semiconductor (currently TowerJazz) and was its CEO for nine years, including when the company went public on NASDAQ. He also played a major role in establishing Saifun Semiconductor, a non-volatile technology start-up, which was subsequently sold to Spansion. He is currently the Chairman and CEO of Zullavision, a company that leverages Israeli technologies to provide innovative solutions for film and TV productions, and he is Chairman and CEO of Amimon, which provides wireless transmissions of HD videos at zero latency.

Atiq Raza (Non-Executive Director): Mr. Raza brings a wealth of experience in the semiconductor industry to Weebit, with a career that spans over 40 years and includes numerous high-profile leadership positions. Notably, he was Chairman and CEO of NexGen, which revolutionised the design of x86 processors before being acquired by Advanced Micro Devices (AMD) in 1996. Mr. Raza then became President and COO of AMD and led its transition from running behind Intel processors to being a direct competitor, gaining significant market share in PCs and the cloud. He has held multiple roles, including investor, CEO and Chairman, at several semiconductor companies, including RMI and Calient Technologies, and served on the boards of Mellanox, Magma Design Automation, Matrix and Solantro Semiconductor Corporation. Mr. Raza is currently the Chairman and CEO at Virsec Systems.

Fred Bart (Non-Executive Director): Mr. Bart has an extensive track record of business success and brings decades of business know-how to WBT. In the 1980s, he was responsible for transforming his family business from a small

operation to a 1,200-employee corporation with a turnover of US$200m. He acquired and turned around several businesses during his impressive career, expanding their operations, growing revenues and helping them become publicly listed. Currently, he is a Chairman and major shareholder of Electro Optics Systems Limited, an ASX-listed defence and space company, and Chairman of Audio Pixels Holdings Limited, an ASX-listed semiconductor company that developed MEMS technology for audio applications. Mr. Bart also holds a wide range of private companies worldwide.

Ashley Krongold (Non-Executive Director): Mr. Krongold has spent 15 years in the investment banking and accounting industries. He was a founding member of Investec Bank Australia, establishing its Melbourne office in 2000 and later leading the bank's Private Client Lending division. He is currently the CEO of the Krongold Group and is also a founding general partner of global equity crowd-funding platform OurCrowd. In addition, Mr. Krongold serves on the boards of various ASX-listed companies, communal charities, foundations and organisations globally. He is also a member of YPO (Young Presidents' Organization), the world's premier peer network of chief executives and business leaders.

Recent M&A implies significant upside potential

Pre-revenue tech companies' valuations are typically driven by the commercial potential of the technology. Although WBT is currently engaging with several potential customers and making inroads into China and Korea, forecasting revenues for 2020 and beyond would be speculative at this stage, given that the timing of new client wins is hard to predict as are the variables in commercial contracts. Therefore, we have used precedent M&A deals to arrive at a relevant valuation estimate.

M&A deals suggest a potential value of A$1.65 per share

The semiconductor industry's willingness to pay for semiconductor IP provides a realistic indication of WBT's potential valuation, in our view. We studied relevant industry deals (Figure 12) under pragmatic scenarios, i.e. an acquisition of the company if and when it succeeds in commercialising its technology.

Figure 12: Relevant M&A transactions in the semiconductor IP space

Announced Date	Acquirer	Target	Transaction Value (USD m)	(AUD m)	Target Sector
03-09-19	Rambus Inc	Silicon IP and Secure Protocols	65	97	Semiconductors / Design & IP
10-05-18	FIT Holding Co., Ltd.	Power Quotient International	153	229	Semiconductors / Memory
09-05-18	Adesto Technologies	S3 ASIC Semiconductors	52	77	Semiconductors / Design & IP
10-01-18	Synopsys Inc	Kilopass Technology	49	73	Semiconductors /Memory
22-09-17	Tallwood Venture	MIPS Technologies	65	97	Semiconductors / Design & IP
29-08-17	Shaanxi International	GigaDevice Semiconductor (Beijing), Inc	362	541	Semiconductors / Memory
12-06-17	Synaptics	Marvell (Multimedia Solutions Business)	95	142	Semiconductors / Design & IP
08-02-17	MaxLinear Inc	Marvell (G.hn assets)	21	31	Semiconductors / Design & IP
03-01-17	Novatek Microelectronics	Faraday (Surveillance SoC Business)	22	33	Semiconductors / Design & IP
04-04-16	GigOptix	Magnum Semiconductor	20	29	Semiconductors / Design & IP
Average			**90**	**135**	

Source: S&P Capital IQ, Pitt Street Research

Although the range of transaction values is quite broad, we believe the average value of A$135m does provide a useful guide to WBT's potential valuation if and when the company starts to gain traction. It would translate into a value of A$1.65 per share.

WBT is addressing a next-generation emerging NVM technology with significant commercial potential. We believe that WBT has achieved several key milestones and is set to transit from the development phase to the commercialisation phase in 2020. We believe this would lead to a substantial ramp-up in revenues in the near to medium term.

While we are not suggesting WBT will be acquired anytime soon, we do believe that the company's IP could potentially be valued at similar levels.

Strategically significant deals point to even higher valuations

Intel acquired two Neuromorphic Computing start-ups for ~US$400m each

Intel has paid even more for comparable technologies on multiple occasions. In August 2016, Intel announced the acquisition of US-based Nervana Systems for US$408m. Nervana is developing a hardware-based neuromorphic computing solution optimised for unsupervised learning**.** In September 2016, Intel also acquired Irish company Movidius, which develops ultra-low power vision processors for computational imaging and vision processing for use in industrial and consumer electronics, including VR devices and drones, for approximately US$400m. In the same month, it acquired Soft Machines, a semiconductor company that develops variable instruction set computing

architecture-based processors and SoC products for all performance-computing platforms, for US$270m.

The revenues of all these companies at the time of acquisition ranged from zero to minuscule, but they were all valued highly due to their strategic importance and potential end use. Longer term, we believe that WBT can possibly achieve similar valuations in a blue-sky scenario, i.e. US$360m or A$536m on average.

US venture capital firms are bullish on emerging memory tech

VC funding to date and typical exit multiples provide guide to future valuations

The average Venture Capital (VC) funding for emerging memory technology companies in the US to date amounts to approximately US$146m, or A$218m (Figure 13), which is 6x to 7x WBT's current market cap.

Assuming these VC's will be looking for exit multiples of 5x to 10x, depending on the stage at which they invested, these funding levels should give an idea of potential future value of these emerging memory companies.

In other words, we believe the potential exit values of VC-owned memory tech firms illustrate the attractiveness of emerging memory technologies from an investment point of view as well as the substantial upside potential for WBT from its current valuation.

Figure 13: VC funding for emerging memory technologies

Company	Technology	Funding to-date (US$ M)
Crossbar	ReRAM	128.3
Everspin	MRAM	116.2
Crocus Technology	MRAM	133.1
Spin Memory	Spin Transfer Torque MRAM	178.8
Avalanche Technology	Spin Transfer Torque MRAM	174.4

Source: Owler.com, Pitt Street Research

Listed ReRAM and MRAM peers are valued substantially higher

Apart from VC and M&A valuations, listed players in the MRAM and ReRAM space, like Everspin (NASDAQ:MRAM, market cap of US$100m, ~A$150m) and Adesto Technologies Corp (NASDAQ:IOTS, market cap US$265, A$395m), are valued substantially higher than WBT. Even an SRAM player like GSI Technology (NASDAQ:GSIT), market cap US$179m (A$267m), is currently valued well above WBT.

Initial valuation of A$1.65 per share

Deal announcements are the obvious share price catalysts

At WBT's current share price, the company's current valuation of approximately A$28m is substantially lower than the valuation seen in recent M&A transactions. As WBT proceeds with concrete discussions with memory players, foundries and IDMs to lice nce the technology on a non-exclusive basis, there will be potential for an open-ended revenue upside. In our view, positive progression of these discussions and potential deal announcements could be the catalysts for a substantial rerate of WBT's valuation.

Assuming WBT will be able to monetise its discussion with potential customers, we believe the initial rerate of the shares should start to bring the company's valuation more in line with the valuation of relevant precedent deals, i.e. well in excess of A$100m. Our initial valuation for WBT is A$1.65 per share.

Conclusion: On the verge of monetisation

WBT is transitioning from its development phase into its commercialisation phase, with multiple collaboration agreements in place. These should expedite the roll out of the company's SiOx ReRAM technology with Embedded ReRAM likely to be the first commercial application area for WBT in 2020. We see strong upside potential, towards A$1.65 per share initially, if and when the company succeeds in closing its first commercial agreements.

Analyst certification

Marc Kennis, lead analyst on this report, has been covering the Semiconductor sector as an analyst since 1997.

- Marc obtained an MSc. in Economics from Tilburg University, The Netherlands, in 1996 and a Post Grad. in investment analysis in 2001.
- Since 1996, he has worked for a variety of brokers and banks in The Netherlands, including ING and Rabobank, where his main focus has been on the Technology sector, including the Semiconductor sector.
- After moving to Sydney in 2014, he worked for several Sydney-based brokers before setting up TMT Analytics Pty Ltd, an issuer-sponsored equities research firm.
- In July 2016, with Stuart Roberts, Marc co-founded Pitt Street Research Pty Ltd, which provides issuer-sponsored research on ASX-listed companies across the entire market, including Technology companies.

Appendix I – SiOx ReRAM technology

ReRAM technology: The right balance between Flash memory and DRAM

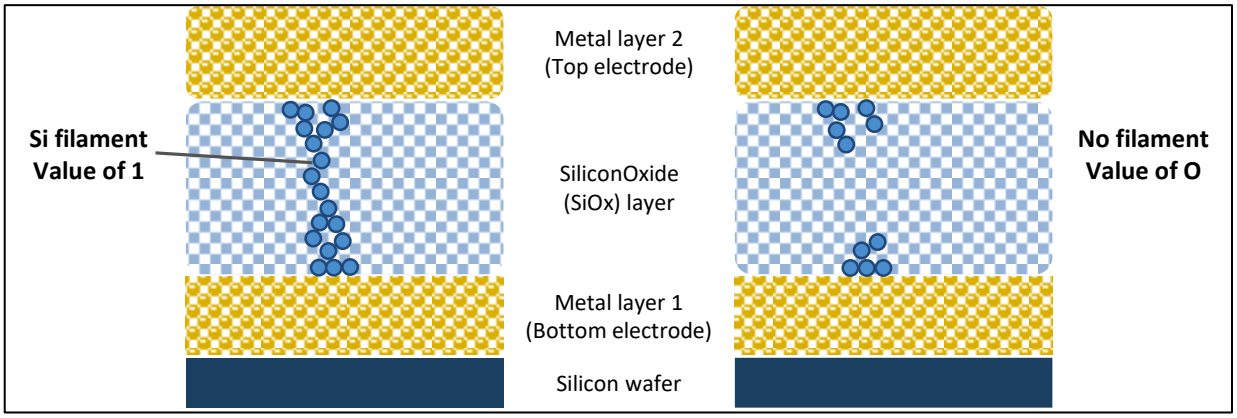
ReRAM is a fast, cost-effective and energy-efficient non-volatile memory (NVM) technology. It can be considered a hybrid memory technology, as it is non-volatile like Flash memory and nearly as fast as DRAM, which is volatile, i.e. a DRAM cell will lose the value (1 or 0) that is stored if the power is switched off. WBT is developing SiOx ReRAM, which, in terms of performance metrics, sits right between Flash and DRAM.

How does it work?

ReRAM is based on resistance rather than electrical charge

Generally, in case of NAND Flash memory, the values of 1 and 0 are attributed on the basis of the trapped electrical charge present in the memory cell's floating gate. However, in case of a ReRAM cell, the values (1 and 0) are attributed based on the resistance level of the cell material sandwiched between the two electrodes (Figure 14). A value of 1 is attributed to a state of low resistivity, while a value of 0 is attributed to a state of high resistivity.

Figure 14: Cell switching by forming and breaking a silicon filament in a SiOx switching layer



Source: Pitt Street Research

There are two ways of changing the resistance level of a ReRAM cell:

i) Through interface switching, which changes the resistivity of the entire layer between the electrodes or

ii) By creating a filament that connects the two electrodes. WBT uses the latter.

The technology WBT is developing is based on the forming of a conductive channel between the two metal electrodes of a ReRAM cell. These electrodes are typically made of metals, such as titanium, tungsten, aluminium or copper. The conductive channel is formed inside a non-conductive SiOx layer.

SiOx has typically been used as an insulating component in semiconductor manufacturing. However, by applying a certain voltage to one of the electrodes, a switchable conductive pathway of silicon nanowires (filament) can be formed within the SiOx layer (Figure 14). In this high-conductivity, low-resistance state, the cell value is 1. By subsequently applying a reverse voltage to the electrode, the filament can be broken down again, effectively switching the memory cell back to the original state of 0.

The actual filament is formed as the applied electrical voltage strips away some of the oxygen atoms in the SiOx layer, leaving the silicon atoms to cluster

and form a conductive silicon pathway to the other electrode. The filament is approximately 5 nanometer (nm) to 7nm in diameter.

The filament diameter is very small and can potentially entail certain major advantages for semiconductor manufacturers if and when SiOx ReRAM is commercialised. Specifically, the potential to embed WBT's memory technology into logic chips and entire systems (SoC) can present substantial commercial opportunities.

WBT uses SiOx in its ReRAM cells, a material that is well understood by the semiconductor industry and has been used in chip manufacturing for decades. We believe that the industry's familiarity with SiOx is a key factor in driving the adoption of WBT's technology among both semiconductor manufacturers and foundries.

SiOx ReRAM's technical parameters validate its commercial use

The endurance and retention levels demonstrated by WBT's technology open up many commercial opportunities

The key parameters for any non-volatile memory are retention and endurance. As demonstrated in the tests conducted by WBT's research partner Leti in May 2019, the company's ReRAM technology is at the forefront of the ReRAM market. The tests demonstrated data retention of over 10 years at 130–150°C, and endurance of a million cycles. Notably, these endurance levels are significantly higher than today's state-of-the-art Flash memory technologies.

Moreover, the retention levels that were achieved at these high temperatures have broadened the scope of potential commercial applications wherein WBT's technology can be used, including the most notable addressable market of Automotive/ADAS/Electric Vehicles.

Appendix II – SWOT Analysis

Strengths & Opportunities	Weaknesses & Threats
- WBT has developed a technology that has clear advantages over incumbent and other emerging memory and storage technologies. - The company's board is extremely experienced in the semiconductor industry, with expertise both on the logic side and on the NVM side of the semiconductor industry. - Because of its Israeli base, WBT is less likely to be impacted by the fallout of the US-China trade war that is impacting US-based semiconductor companies. - WBT's current industry collaborations provide line of sight to maiden revenues in 2020. - Because embedded memory is omnipresent in today's electronics, WBT addressable end-markets are extremely large and diverse. - In addition to the embedded memory market, WBT's current focus, discrete memory devices and Neuromorphic Computing present equally interesting market opportunities in due time.	- WBT is a small player in an industry dominated by very large companies, which makes balanced partnering more difficult. - The company will likely require additional funding, which makes it highly dependent on financial market sentiment when it comes to capital raising. - WBT is unlikely to be able to progress all commercially interesting projects simultaneously due to funding restrictions, which may lead to missed commercial opportunities down the line. - IP theft continues to be an issue in China, which makes partnering with Chinese companies substantially more challenging than partnering with companies from other countries, including Korea. - Industry incumbents and VC-backed emerging memory companies may be faster in developing commercially-ready technology, which would inhibit WBT's growth potential.

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